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By

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Learned Principles of Organization in Memory[1]

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INTRODUCTION

THE process of forgetting is characterized not only by decreases in the amount retained but also by qualitative changes in the material that is reproduced. Such qualitative changes may be systematic in nature and develop in orderly, predictable ways. Thus visual figures reproduced from memory often show characteristic changes as compared with the original. Not only are details omitted, but the reproductions may be simpler and more regular than the original figures and show assimilation to conventional objects. Many investigators have reported the presence of such changes, although there has been considerable disagreement about the relative frequency of systematic and unsystematic errors of reproduction.[2] Simplification and assimilation to conventional patterns have also been noted in reproductions of verbal materials (1, 2).

The processes mediating such qualitative changes have long been a focus of dispute among conflicting theories of memory. According to Gestalt theory, errors of reproduction reflect the development of memory traces in the direction of increasing conformity to the laws of perceptual organization. In support of this view, evidence has been offered that (*a*) reproductions tend to be "better" figures than the originals, and (*b*) changes in reproductions develop *progressively* in the direction of greater *prägnanz* (5, 8, 11). Both lines of evidence have been questioned seriously on empirical as well as methodological grounds (3, 4, 10).

Without committing himself to a physiological trace hypothesis, Bartlett (2) has emphasized the progressive assimilation of mnemonic material to organized and cohesive schemata. Remembering is a process of reconstructing past events in conformity with such schemata. These schemata are influenced to an important degree by the subject's interests and attitudes and hence are constantly reorganized as such interests and attitudes change and develop.

Exponents of a "true forgetting" theory have recognized the importance of perceptual habits functioning during original learning but at the same time have emphasized the influence of response habits at the time of reproduction (3, 10). During the original exposure to the stimulus, the subject's perceptual habits lead to selective emphasis on some features of the stimulus. Frequently verbal labels are attached to all or part of the stimulus. A true process of forgetting is assumed to run its course between the end of learning and the time of recall. "The trace after a sufficient interval no longer defines any complete figure" (10, p. 81). The verbal labels and/or some of the features emphasized in the original perception do, however, remain available. The subject builds his reproduction around these cues; the more true forgetting there has been, the more the specific form of the reproduction is determined by the habits and skills which the subject brings to the performance of his task.

The perceptual habits and performance factors responsible for systematic changes in the reproductions have usually had to be inferred after the fact. Investigators have often experienced considerable difficulties in classifying the changes in reproductions, and inferences concerning the categorizations of the stimuli by the subjects have been correspondingly hazardous. If learned habits of categorizing and responding are to be firmly established as determiners of systematic memory change, it is necessary to "build in" such habits under controlled experimental conditions and to trace resulting changes in memory performance.

[1] A major part of this research was facilitated by a grant from the Laboratory of Social Relations, Harvard University. The writer expresses his sincere appreciation to Dr. Leigh Minturn for her invaluable assistance.

[2] An excellent review of the experimental literature on memory for form is given by Woodworth (10).

In the present study an attempt was made (*a*) to train *S*s to categorize a group of stimuli in accordance with a specific set of rules and (*b*) to demonstrate orderly and predictable changes in the memory for these stimuli resulting from the categorizing habits.

THE PLAN OF THE EXPERIMENTS

A series of experiments was performed. The same stimuli, a group of geometric designs, were used throughout. Standard training procedures were used with the experimental *S*s to establish habits of categorizing the stimuli in accordance with a set of rules which formed a code for the classification of the designs. Control *S*s had the same amount of exposure to the stimuli as did experimental *S*s but were not trained in the use of the code. In successive experiments, various consequences of the differential training procedures for memory performance were investigated.

In Experiment I, the effects of preliminary training on immediate memory for a series of designs were measured. Experimental and control *S*s were compared with respect to both the amount of material retained and qualitative changes in reproduction.

In Experiment II, memory changes over time were related to the conditions of preliminary training. The hypothesis tested was that training in categorization would result in a progressive tendency over time to reproduce stimuli in conformity with the principles of the code.

In Experiment III, the effects of preliminary categorization training on retroactive inhibition were investigated. The hypothesis tested was that categorizing habits would reduce susceptibility to retroactive inhibition.

EXPERIMENT I: THE EFFECTS OF CATEGORIZING HABITS ON MEMORY FOR A SERIES OF DESIGNS

Stimulus materials. The stimulus materials used throughout the series of experiments are shown in Fig. 1. There are eight basic pairs of designs called *code pairs*. From each code pair, a set of four other pairs, called *breakdown pairs*, is derived. The breakdown pairs are derived from the code pairs according to a fixed principle: a line is removed from one member of the code pair, and this same line is added to the other member of the pair. The breakdown pairs are constructed in such a way that the added line is not obscured by any other line in the figure to which it has been added. The principle governing the derivation of breakdown pairs from code pairs, then, is the addition and subtraction of lines, holding the total number of elements in a pair constant. Within a given set, all

FIG. 1. Stimulus materials used in all the experiments. There are four breakdown pairs for each basic code pair.

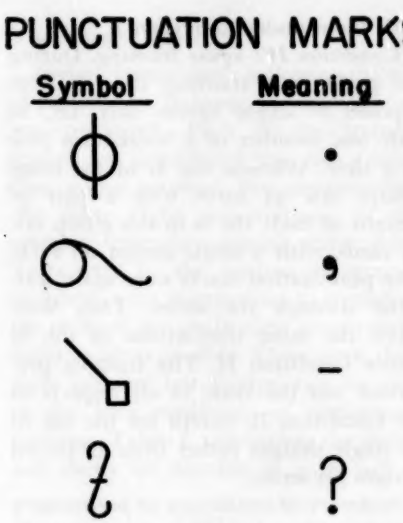

FIG. 2. Punctuation marks used in the memory series.

breakdown pairs add up to the basic code pair.

In addition to the eight code pairs and their breakdown pairs, a series of punctuation symbols was used. These symbols are reproduced in Fig. 2. It was desirable to include single, as well as paired, items in the series of stimulus designs, and the punctuation marks were used for that purpose.

METHOD

Preliminary Training

The major experimental variable was the type of preliminary training which *Ss* received before learning and reproducing a series of breakdown pairs. There were four conditions of training: (*a*) code training, (*b*) pair training, (*c*) code transfer training, (*d*) figure training.

Condition I: code training. The *Ss* in this group received explicit instruction and training in the derivation of breakdown pairs from code pairs. They were given the following instructions:

> Your first task is to learn a simple artificial language, made up of geometric figures. In this language we have code figures which can be broken down in several different ways. Here is the first code and its breakdowns. (At this point *E* exposed a cardboard strip showing an example of a code and its breakdowns.) You can see that what we do to form a breakdown is to take a line from one of the code figures and add it to the other. That is, the principle of the code is addition and subtraction of lines. Therefore, if you know the original code figures, one of the breakdown figures will enable you to reconstruct the other breakdown figure. I will expose similar codes and breakdowns for a limited period of time. Study them carefully and try to remember them since you will be asked to draw them later. (At this point cardboard strips showing the eight codes and their breakdowns were exposed for 15 sec. each.) In this artificial language, we also have punctuation marks—a period, a question mark, a comma, and a dash; these figures have no breakdowns. (*E* exposes strip with punctuation marks for 15 sec.)

After this preliminary exposure to the codes and their breakdowns, the training proper was begun. The *Ss* were given record sheets, marked off into squares, and given further instructions as follows:

> Now I want you to use the codes which you have just learned. I will present pairs of breakdowns. Look at them and when I have taken the card away, draw them and then combine them to form the appropriate code symbols. Put both the breakdowns and the code in one space. Please do not start to draw until I have put down the card. When you have finished drawing each breakdown and its code, I will show you the correct code so that you can see if you are right in reconstructing the code figure. Do not change your drawing after you have seen the code, but try and remember for the next time if you have made a mistake.

Breakdown pairs were exposed for 3 sec. As soon as the card showing the breakdown pair was removed, *Ss* reproduced it from memory and added the appropriate code pair. Immediately after *Ss* completed their drawing, the correct code pair was shown for 2 sec.

The series of 32 breakdown pairs (four for each of the eight codes) was presented twice. The punctuation marks were interspersed and copied by the *Ss*.

Different random orders were used for the two presentations.

Condition II: pair training. These *Ss* were exposed to breakdown pairs only and were neither shown the code pairs nor did they receive any instruction in the principle of derivation of the breakdown pairs. Throughout their preliminary training, however, only paired breakdown figures were presented. The *Ss* in this group were, therefore, trained with exactly the same stimuli as were the *Ss* under Condition I, except for the omission of the code pairs. The following instructions were given:

> This will be a test in speed and accuracy of reproducing geometric designs. I will present a series of geometric figures which you are to draw on the paper you have before you. I will go through the pack of figures once so that you can look at them. The first time you do not have to draw the figures. (The *E* then exposed the series of breakdown pairs, showing the cards for 3 sec. each.) Now I will go through the pack of cards again. This time I want you to look at the designs carefully and when I have taken the card away, draw what you have seen. Please do not start to draw until I have put down a card.

The series of 32 breakdown pairs and the punctuation marks were then presented twice, each time in a different random order. Each card was presented for 3 sec. As soon as a card was removed, *S* reproduced it from memory on a record sheet marked off into squares.

Condition III: code transfer training. This condition of training was identical with Condition I (pair training), with one exception: only half the breakdown pairs, i.e., two per code, were used, These *Ss* thus, received explicit information about the codes and the principles of breakdown derivation but experienced only half as many examples as the *Ss* under Condition I. The specific breakdowns with which they were trained were different from those used later in the memory series. The instructions and conditions of training were identical with those under Condition I.

Condition IV: figure training. During the preliminary training, these *Ss* were exposed to single figures only, i.e., to only one member of a breakdown pair at a time. Whereas the *Ss* in the other groups saw 32 cards with a pair of designs on each, the *Ss* in this group saw 64 cards, with a single design on each. The punctuation marks were again scattered through the series. They were given the same instructions as the *Ss* under Condition II. The training procedure was the same in all respects as for Condition II, except for the use of 64 single designs rather than 32 paired designs per series.

Summary of conditions of preliminary training. We may summarize the conditions of preliminary training in terms of the types of preparation which *Ss* received for the memory task that was to follow. The information provided by the preliminary training may be classified as: (*a*) familiarity with the individual designs to be used in the memory series; (*b*) familiarity with the specific pairs to be used in the memory series; and (*c*) training in the priniciple according to which breakdown pairs are derived from code pairs. Condition I (code training) provides all three types of preparation whereas in the other conditions at least one is omitted.

Evaluation of preliminary training. The effectiveness of the different training procedures could be checked by means of *Ss*' reproductions during the training series. Only *Ss* who gave at least 80 per cent correct reproductions on the second training series were retained in the experiment. In all cases, this criterion was well exceeded on the second training trial. It is possible to assert, therefore, that *Ss* had acquired the information which the different training procedures were intended to provide.

The Memory Tests

Design. Immediately following the end of preliminary training, the memory task was presented. Each of the training groups was subdivided into two groups. One group received five presentations, the other eight presentations, of the memory series in constant serial order. Tests were by the method of retained members, with instructions to reproduce the series of designs in their proper serial order as far as possible. There were, thus, eight memory test groups, two for each of the four conditions of preliminary training. Table 1 summarizes the design and shows the number of *Ss* in each of the groups. The variation in the number of presentations of the series was introduced in order to study the relation between the effects of preliminary training and the degree of learning prior to the retention test.

TABLE 1

SUMMARY OF DESIGN OF EXPERIMENT I

Condition of Training		Number of *Ss*	
		5 Presentations	8 Presentations
I	Code training	9	8
II	Pair training	10	12
III	Code transfer training	8	10
IV	Figure training	14	10

The memory series. All groups learned the same series of designs. This series is reproduced in Fig. 3. The series consisted of 24 figures—ten breakdown pairs and four punctuation marks. The punctuation marks appear in positions 2, 10, 18, and 24. The two members of a given breakdown pair are, of course, always contiguous except for the cases in which they are separated by a punctuation mark. The ten breakdown pairs represent five of the codes used in the original training, each of the codes being represented by two pairs. The inclusion of two pairs each from a given code served to increase the difficulty of the series since there was considerable opportunity for intraserial interference. It was believed that a difficult series would be favorable to the measurement of the differential effects of preliminary training.

FIG. 3. The memory series used in Experiment I.

The cards were presented at a 3-sec. rate, with 10 sec. between series. Time was kept by means of a metronome.

Instructions. The instructions for the memory series varied with the nature of the preliminary training. The *Ss* who had received code training (Conditions I and III) were requested to apply their preliminary training as much as possible to the task of memorizing the series of stimulus figures. The other *Ss* (Conditions II and IV) were merely reminded that the designs to be memorized were like those used in the preliminary training. The instructions stressed the fact that the stimuli were to be remembered in their proper order.

At the end of the series of presentations, *Ss* reproduced their designs on a sheet divided into squares numbered

from 1 to 24. The *Ss* were asked to reproduce the designs in order but to put down whatever figures they remembered even if they were uncertain about the order. They were encouraged to guess when doubtful about a given design. There was no time limit for the retention test.

Subjects. The *Ss* were undergraduate students at Harvard University and Radcliffe College. They did not know the purpose of the experiment and were assigned to the experimental conditions at random.

Results

All protocols were scored independently by two judges, and only those reproductions were considered correct on which both judges agreed. Interscorer reliability was very high throughout all the experiments, with 95 per cent agreement or better.

Retention of individual designs. We shall consider first the number of individual designs correctly reproduced. Table 2 and Fig. 4 show the number of individual designs correctly reproduced after five and eight presentations of the memory series. Clearly, the conditions of preliminary training influence the number of individual designs retained.

After five presentations of the series, *Ss* in Condition I (code training) and Condition II (pair training) show considerably higher retention for individual designs than do *Ss* in Condition III (code transfer training) and Condition IV (figure training). Analysis of variance of the retention scores yields an F ratio of 3.20 ($df = 3$ and 37, $p = .01$–$.05$). Conditions I and II both involved preliminary training with the *specific pairs* used in the memory series. Neither Condition III nor Condition IV included such training. The *Ss* in Condition III were instructed in the principle of the code but were not exposed to the specific pairs of the memory series. The *Ss* in Condition IV were familiar with the individual designs but had not experienced them as pairs. It appears that experience with the specific pairs of the memory series aids in the retention of individual designs. Instruction in the principle of the code does not by itself lead to an increase in the retention of individual figures.

The results obtained after eight presentations of the memory series help to throw further light on the differential effects of the preliminary training. The only substantial difference is between Condition III and all the other conditions. Analysis of variance of the retention scores for the eight-presentation group yields an F of 4.88 ($df = 3$ and 38, $p < .01$). Condition III is the only

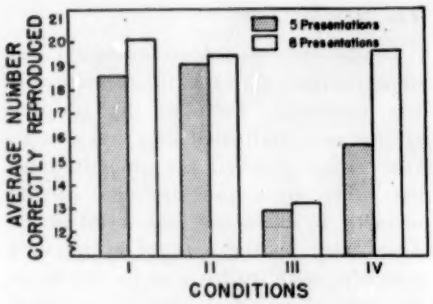

Fig. 4. Average number of designs correctly reproduced by the various groups in Experiment I.

TABLE 2

Average Number of Designs Correctly Reproduced by the Different Groups in Experiment I

Condition of Training	Number of Presentations	
	5	8
I	18.56	20.12
II	19.10	19.42
III	12.88	13.60
IV	15.07	19.58

condition of preliminary training which did not include experience with the specific designs used in the memory series. The fact that even after eight presentations of the series, Condition III lags behind all other conditions, including Condition IV, indicates that experience with the specific memory stimuli (paired or unpaired) is more beneficial for retention of individual designs than code training using a different set of specific stimuli.

As far as retention of individual designs is concerned, we conclude that familiarity with the specific stimuli significantly influences retention. Previous experience with specific pair sequences is more beneficial than experience with individual designs. Instruction in the principle of the code per se had no significant effect.

Conformity to code principles. Let us consider next qualitative differences in *Ss'* reproductions which may be ascribed to the effects of preliminary training. Does preliminary training in the principles of the code produce a systematic tendency to conform to these principles in the reproduction of the designs?

To measure the extent of conformity to the learned principles of the code, the following analysis was carried out. First, all those cases were examined in which the two members of a breakdown pair were reproduced in immediate succession so that their contiguity in the series was preserved in the reproductions. All such reproductions were then classified as either *code preserving* or *code destructive.* A code-preserving pair was one which conformed to the principle of the code so that the basic code pair could be formed by subtracting a line from one member of the pair and adding it to the other. Such code-preserving pairs resulted if (*a*) both members of the pair were reproduced without error, or (*b*) if complementary errors were made in both members of the pair. Examples of such complementary errors are shown in Fig. 5a and 5b. Fig. 5a shows the reproduction of a breakdown pair from Code I (cf. Fig. 1). The direction of the diagonal has been reversed in both members, i.e., two compensatory errors are made. Both individual designs are incorrect, but as a pair they conform to the principle of the code. Fig. 5b shows a reproduction of a breakdown pair from Code IV. Again, the individual members are incorrect but the pair conforms to the code. Code-destructive pairs resulted when (*a*) one member of the pair was correct and the other member was incorrect or (*b*) both members were incorrectly reproduced and the two errors were not compensatory.

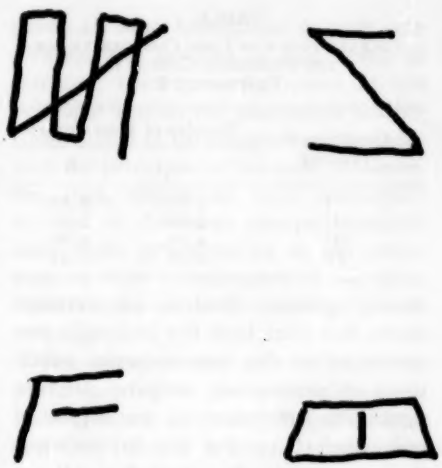

FIG. 5a (top) and 5b (bottom). Examples of code-preserving errors.

An *index of code conformity* was computed for each *S* by subtracting the number of code-destructive pairs from the number of code-preserving pairs. Table 3 shows the average index of code conformity for the eight experi-

TABLE 3
AVERAGE INDEX OF CODE CONFORMITY FOR THE DIFFERENT GROUPS IN EXPERIMENT I

Condition of Training	Number of Presentations	
	5	8
I	6.67	8.00
II	4.80	5.17
III	4.00	3.80
IV	2.21	5.33

mental groups. Analysis of variance shows that after both five and eight presentations of the memory series conditions of preliminary training produce significant differences in the degree of code conformity. For the five-presentation groups, the F ratio is 6.00 ($df = 3$ and 37, $p < .01$); after eight presentations, F is 3.86 ($df = 3$ and 38, $p = .01$–$.05$).

After five presentations of the series, i.e., with the relatively lower degree of learning, *Ss* who had received explicit instructions in the principle of the code (Condition I) show the highest degree of code conformity. As might be expected, the group that had neither code instruction nor experience with paired designs (Condition IV) shows the lowest degree of code conformity, with Condition II (pair training) and Condition III (code transfer training) occupying intermediate positions. It is important to note that the rank order of conditions in code conformity is not the same as for reproduction of individual designs. The two scores measure, at least in part, different characteristics of memory performance.[3]

After eight presentations, i.e., with the relatively higher degree of learning, Condition I maintains its superiority in code conformity. The other groups are now more nearly alike. It is particularly interesting to note that Condition IV is no longer inferior to Condition III, but, as a matter of fact, has a higher index of code conformity.

The findings concerning the code conformity index may be summarized as follows: There is maximum code conformity when the preliminary training combines instructions in the principles of the code and experience with the specific pairs of the memory series (Condition I). At the lower level of learning, experience with the specific pairs (Condition II) and instructions in the principles of the code (Condition III) produce approximately equivalent degrees of conformity which are higher than those obtained after training with individual figures (Condition IV). In the long run, i.e., at the higher degree of learning, familiarity with the specific designs proves, however, more effective in producing code conformity than mere instructions in the principles of the code. With repeated presentations of the memory series all *Ss* may be assumed to learn, explicitly or implicitly, some of the principles of the code. The more familiar the *Ss* are with the specific designs, the more effectively can they apply these principles; hence Condition IV surpasses Condition III at the higher level of learning.

CONCLUSIONS

Experiment I has shown that the nature of the preliminary training influences the amount retained and the quality of the reproductions. During this training *Ss* acquire categorizing habits[4]

[3] The two measures are not, of course, entirely independent since a code-preserving pair results if two individual designs are reproduced correctly and in sequence. The correlation between the two measures can, however, vary over a wide range.

[4] We have discussed the acquisition and functioning of categorizing habits elsewhere under the heading of "hypotheses" (9).

which pertain both to the individual designs and to the relations among the members of the series. These categorizing habits influence (*a*) the ways in which the members of the series are associated during learning and (*b*) the ways in which the designs are reconstructed at the time of recall.

The results thus far point primarily to the importance of familiarization with the learning materials prior to training. The relatively poor performance of *Ss* in Condition III, who had instruction in the principles of the code but were not exposed to the specific designs, supports this conclusion. By the same token, the relatively high performance of *Ss* trained with the memory pairs but without explicit instructions in the code (Condition II) emphasizes the importance of familiarization with the specific memory materials. Explicit instructions in the principles of the code did, however, have a significant though limited effect. Condition I (code training) surpasses all other conditions in code conformity, and does so at both levels of learning. Clearly, verbalization of the principle aids in the association and reconstruction of the designs in accordance with the principles of the code. However, the high degree of code conformity reached by the other groups, especially after eight presentations of the series, suggests that verbalization of the principle is not a necessary condition of code conformity.

The question now arises whether explicit training in the principle of the code assumes increasing importance as the time interval between learning and retention test is increased. The emphasis on the progressive nature of the changes in previous studies of memory for designs suggests that such may well be the case. It is to the question of progressive effects of preliminary training with increasing retention intervals that Experiment II addresses itself.

EXPERIMENT II: PROGRESSIVE MEMORY CHANGE AS A FUNCTION OF PRELIMINARY TRAINING

Experiment II was designed to test the hypothesis that the longer the time interval between learning and retention the greater the effects of preliminary training on the reproductions. A critical test of this hypothesis was provided by including among the stimulus materials items which violated the principles of the code. These error figures provided controlled opportunities for tendencies toward rectification or normalization of the designs to manifest themselves. Would the disposition to rectify the errors in accordance with the principles of the code show a progressive increase in time?

Method

Preliminary training. Only two of the conditions of preliminary training used in Experiment I were used in this study, viz., Condition I (code training) and Condition II (pair training). These conditions had yielded the smallest differences in the immediate retention test, both in amount retained and in code conformity. If the difference between these two conditions could be increased with longer retention intervals, the argument for progressive effects of explicit code training could be made *a fortiori*. That is, the choice of these two conditions of preliminary training put the hypothesis that

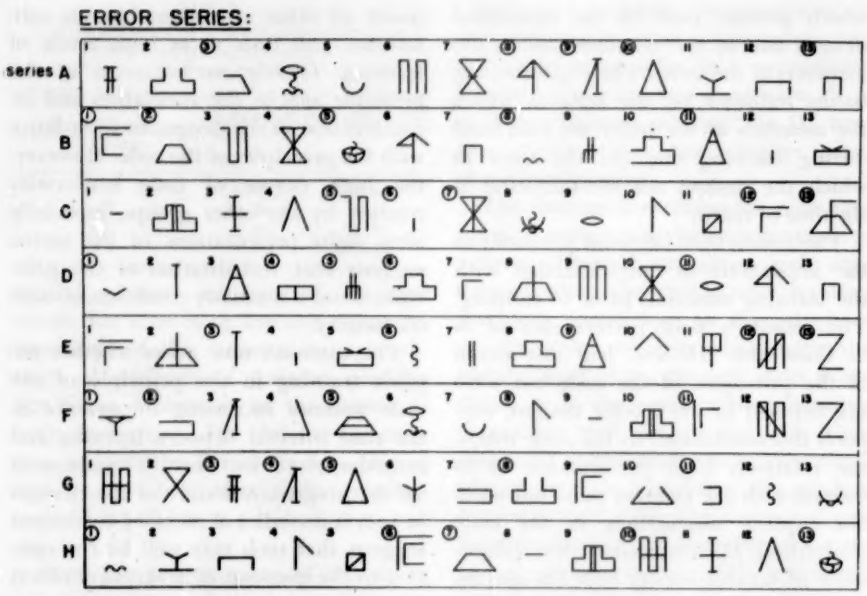

FIG. 6. The eight memory series used in Experiment II. The numbers of the figures representing violations of the code are encircled.

code training exercises progressive effects in time to the most exacting test possible.

The procedures used in the preliminary training were exactly identical with those described in Experiment I. Again only *Ss* who met a criterion of 80 per cent correct responses during the preliminary training were used.

The memory series. The memory series consisted of 13 figures. Of these 13 figures, eight form pairs in conformity with the code. The other five figures represent violations of the code principles as follows: (*a*) one "code-destructive" pair, the members of which do not add up to the basic code, (*b*) a "separated pair," i.e., a pair the two members of which are separated from each other by other figures, and (*c*) one of the figures is a "singlet," i.e., only one member of the pair is given, with the other member missing from the series.

In order to make the effects of these errors independent of specific figures and of serial position, different breakdowns were used as error figures, and the positions at which the errors appeared were randomized. Distribution of the errors among different specific figures and serial positions resulted in eight different memory series. These series are reproduced in Fig. 6. Series A may be used to illustrate the systematic errors introduced into the series. No. 3 is a singlet since its "mate" is missing from the series. Nos. 8 and 13, though they form a correct pair, are separated by other figures. Nos. 9 and 10, although resembling breakdowns of Code VIII, do not add up to the code pair and are therefore a code-destructive combination. The numbers designating the error figures are encircled in all series.

The learning and memory test instruc-

tions were the same as in Experiment I. The series was presented four times. The figures were presented at a 3-sec. rate, with 10 sec. between series.

Retention intervals. Tests of retention were given after four different time intervals: immediately, one day, one week, and two weeks after learning. With two conditions of preliminary training and four retention intervals, there were eight different experimental groups.

Subjects. A total of 128 *Ss* took part in the experiment, 16 in each of the eight experimental groups. The *Ss* were students at Harvard University and Radcliffe College. They did not know the purpose of the experiment and were assigned to the experimental groups at random.

Results

The results for normal figures, i.e., those conforming to the code, and error figures, i.e., those violating the principles of the code, will be presented separately. The effects of preliminary training on the retention of both types of figures will be considered.

TABLE 4

Average Number of "Normal" Designs Correctly Reproduced by the Different Groups in Experiment II

Time of Retention Test	Condition of Training	
	I	II
Immediate	6.00	7.00
1 day	3.56	4.69
1 week	1.88	2.69
2 weeks	2.12	1.81

Retention of normal figures. Table 4 and Fig. 7 show the number of figures reproduced correctly as a function of preliminary training and time interval. In general, retention decreases as a function of time interval. Both conditions show a sharp initial drop in retention after one day, and a somewhat less pronounced drop between one day and one week. Condition II shows a further drop between one week and two weeks whereas there is a slight rise for Condition I during that interval.

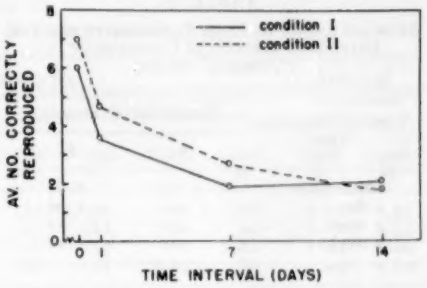

Fig. 7. Average number of "normal" figures correctly reproduced by the various groups in Experiment II.

The interaction between condition of preliminary training and time interval is of interest. At the shorter retention intervals, Condition II is superior to Condition I. As the time interval is lengthened, this difference between the conditions diminishes and finally is reversed on the two-week test. Analysis of variance shows that conditions of preliminary training, length of time interval, and the interaction of these variables are all significant sources of variance. The F ratios are as follows: for conditions of preliminary training, 5.29 ($df = 1$ and 120, $p = .01$–$.05$); for time intervals, 138.98 ($df = 3$ and 120, $p < .01$); for interaction, 15.84 ($df = 3$ and 120, $p < .01$).

A very similar picture emerges when we consider conformity to the principles of the code in the reproduction of normal pairs (Table 5 and Fig. 8). As in Experiment I, all reproductions of pairs were classified as either code preserving or code destructive. For each *S*, an index of code conformity was computed by sub-

TABLE 5

AVERAGE INDEX OF CODE CONFORMITY FOR THE DIFFERENT GROUPS IN EXPERIMENT II ("NORMAL" PAIRS)

Time of Retention Test	Condition of Training	
	I	II
Immediate	1.69	2.62
1 day	−.44	1.06
1 week	.75	.12
2 weeks	.19	−.12

tracting the number of code-destructive pairs from the number of code-preserving pairs.

Again Condition I is inferior to Condition II at the shorter retention intervals, and again the difference between the conditions is reversed at the longer intervals. We note that the reversal occurs earlier (at one week) for the code conformity index than it did for retention of individual figures (at two weeks). Analysis of variance again shows the interaction of conditions of preliminary training and time intervals to be statistically significant ($F = 4.74$, $df = 3$ and 120, $p < .01$). Conditions in and of themselves are not a significant source of variance ($F = 2.62$, $df = 1$ and 120, $p > .05$), which was to be expected in view of the striking reversal in the difference between conditions at the longer time intervals. Length of time intervals is, of course, a highly significant source of variance ($F = 17.26$, $df = 3$ and 120, $p < .01$).

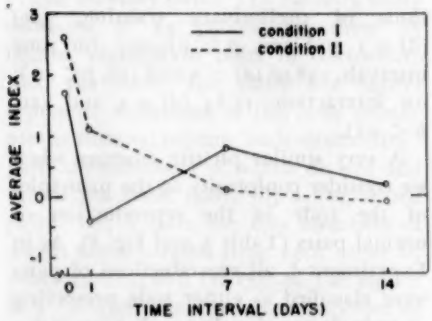

FIG. 8. Average index of code conformity for the various groups in Experiment II.

At the shorter retention intervals, then, Condition II is superior to Condition I both in retention of individual figures and in code conformity; at the longer retention intervals Condition I tends to be superior. Condition I, it will be remembered, included explicit instruction in the principles of the code whereas Condition II did not. The inferiority of Condition I at the shorter retention intervals is probably due to the presence of error figures in the memory series. For *Ss* who have received code training, these error figures violate the principles they have just learned and hence serve as a source of interference. The presence of the error figures gives rise to response tendencies which are in conflict with the application of the principles of the code. There is less interference from the error figures under Condition II since the preliminary training does not involve explicit verbalization of the principles of the code. Why, then, the steady decrease, and eventual reversal in time, of differences between Condition I and Condition II?

We may assume that individual figures are forgotten at a faster rate than are the general principles of the code, especially if the latter have been explicitly verbalized. As the time intervals are lengthened, there is more and more "true forgetting" for both normal and error figures, and *Ss*' reproductions are increasingly governed by the categorizations and labels that had been attached to the stimuli during preliminary training and during learning. At the longer time intervals, memory performance becomes reconstruction around a general schema (2) rather than rote reproduction. At these

TABLE 6
AVERAGE NUMBER OF DIFFERENT TYPES OF REPRODUCTIONS OF ERROR FIGURES

Time of Retention Test	Type of Reproduction								Index of Persistence of Error	
	Unchanged		New Errors		Rectifications		Omissions			
	Cond. I	Cond. II	Cond. I	Cond. II	Cond. I	Cond. II	Cond. I	Cond. II	Cond. I	Cond. II
Immediate	1.94	2.44	.81	.50	.12	.00	.12	.06	2.63	2.94
1 day	.56	.94	1.62	1.50	.31	.12	.44	.44	1.88	2.31
1 week	.62	.62	1.19	1.56	.38	.19	.81	.62	1.44	2.00
2 weeks	.44	.50	.94	1.75	.44	.12	1.19	.62	.94	2.12

longer intervals, then, explicit training in the code should become increasingly effective whereas response tendencies associated with individual figures, including error figures, lose in importance. The more memory performance comes to depend on schematic reconstruction the more beneficial is explicit verbalized training in the principles of the code; hence the superiority of Condition I over Condition II at the longer retention intervals.

Our analysis has implications for the retention of the error figures. In general, we would expect Condition I to be less favorable than Condition II to correct reproduction of the errors. The more explicit the statement of the code principles has been the more the error figures represent a violation of *Ss'* expectancies concerning the series. In terms of the argument just presented, the differential effects of preliminary training on the reproduction of errors should be greatest at the longer retention intervals.

Reproduction of errors. The following classification was used in scoring reproductions of the error figures: (*a*) unchanged reproduction, i.e., reproduction of the errors as presented; (*b*) substitution of a new error for the original one, i.e., changes in the original figures which continue to violate the principles of the code; (*c*) omission; (*d*) rectification, i.e., changes in reproductions which make the figures conform to the principle of the code. Table 6 shows the average number of reproductions falling into each of these categories for the different combinations of preliminary training and retention intervals.[5] We shall examine each of the four categories for indications of systematic trends.

1. Unchanged reproductions. Under both conditions of preliminary training, the number of unchanged reproductions steadily decreases as the retention interval is lengthened. In general, *Ss* trained under Condition I give fewer unchanged reproductions than do *Ss* trained under Condition II. This difference between conditions does not, however, show a systematic increase as a function of retention interval.

2. Substitution of new errors. At the earlier retention intervals, Condition I gives more substitute errors than does Condition II; at the later retention intervals, the rank order is reversed.

3. Omissions. At the earlier retention intervals, there is no difference between scores under the two conditions. At the later retention intervals *Ss* under Condition I have higher omission scores than do *Ss* under Condition II. This difference first appears on the one-week test

[5] For purposes of this tabulation, the two error pairs and the singlet are treated as one unit each so that the scores in the four categories always add up to three.

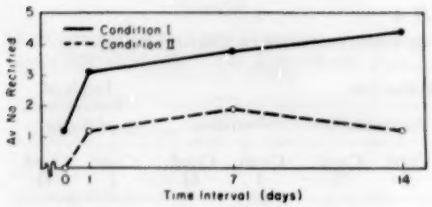

FIG. 9. Average number of error figures rectified by the various groups in Experiment II.

and shows a considerable increase on the two-week test.

These three findings suggest the following picture of the course of memory for errors following the two conditions of preliminary training. The *Ss* trained under Condition I, for whom the errors violate explicitly stated and frequently confirmed principles, show poorer retention of errors than do *Ss* trained under Condition II; they (*a*) give fewer unchanged reproductions of the errors, (*b*) introduce new errors at an earlier stage, and (*c*) show a progressive tendency to omit more and more of the error-figures altogether. Explicit training in the code reduces the over-all level of retention for error figures, makes error figures more liable to change and distortion, and with increasing time interval favors complete elimination of the error figures. Condition II, which did not provide explicit training in the principles of the code, shows all these effects to a smaller extent than does Condition I. The difference between the two conditions, particularly as regards substitute errors and omissions, is greatest at the longer retention intervals. It appears that the differences in preliminary training have their maximum effect at the longer retention intervals.

4. Rectifications. The most direct evidence for systematic effects of preliminary training comes from the reproductions in which error figures are rectified so as to conform to the principles of the code. In the case of the singlet, such rectification would take the form of supplying the missing member of the pair; the separated pair is rectified if the two members are reproduced next to each other; the code-destructive pair is rectified if the figures are changed so as to add up to the code symbol.

Figure 9 shows the average number of rectifications obtained from the different experimental groups. The absolute number of rectifications is small, which is not too surprising since there were only three violations of the code principles in each series and there was a considerable amount of forgetting. Nevertheless, two trends stand out clearly. At all retention intervals, Condition I gives more rectifications than does Condition II, and Condition I gives much clearer indication of a progressive trend in the number of rectifications over time. Again the two conditions diverge most at the longer retention intervals. As the amount of "true forgetting" for individual figures increases in time, reconstruction in terms of the code principle is more and more likely to produce rectifications.

An index of the persistence of error. The temporal trends in the memory for errors can be summarized and pointed up by means of an index of the persist-

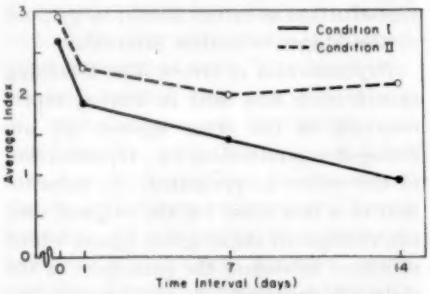

FIG. 10. Average index of the persistence of error for the various groups in Experiment II.

ence of error. For each *S*, the number of rectifications was subtracted from the total number of errors reproduced (both unchanged errors and substitute errors). This difference score, then, is a measure of the extent to which errors violating the rules of the code appear in the reproductions. Table 6 and Fig. 10 show the average index of persistence of error for the different combinations of preliminary training and time interval. At all time intervals, the index is smaller for Condition I than for Condition II. The difference between the conditions increases progressively as the retention interval is lengthened. An analysis of variance was performed on the index scores. Time interval is a highly significant source of variance ($F = 10.05$, $df = 3$ and 120, $p < .01$) as is the condition of preliminary training ($F = 12.50$, $df = 1$ and 120, $p < .01$). The interaction of time interval and condition of preliminary training fails, however, to reach significance ($F = 1.25$, $df = 3$ and 120, $p > .05$). Condition I has a lower index than Condition II at all intervals, and the increase in the difference is not sufficient to reach significance. Nevertheless, the internal consistency of the different analyses suggests that the progressive divergence of the two conditions in time represents a real trend.

Conclusions

Experiment II has shown that conditions of preliminary training have progressive systematic effects on memory performance as the retention interval is lengthened. Manipulation of the length of the retention interval has made it possible to bring out important differences between explicit training in the principles of the code (Condition I) and preliminary familiarization with the pairs of the memory series (Condition II). It is at the longer intervals that instruction in the rules of organization has its clearest effects, both on the reproduction of normal figures in conformity with the code and on the rectification and omission of errors.

Our findings support Woodworth's (10) view that changes in the reproduction of designs depend both on the amount of "true forgetting" since the end of training, and on the habits and skills with which *S* enters the retention situation. The poorer the memory for the specific details of the original figures, the greater is the weight of these habits and skills in determining the reproductions. In this experiment, we have manipulated, under controlled conditions, the habits which *S* could bring to bear on the reproductions. These manipulations resulted in systematic and progressive changes in the reproductions. No appeal to the "development of the memory trace in accordance with principles of organization" is necessary to account for these findings. On the contrary, our results show that progressive memory changes can be built into the subject by giving him information concerning the nature of the stimuli and by teaching him rules for organizing these stimuli. When called upon to reproduce a form which he cannot clearly recall, *S* uses this information and applies these rules just as he uses whatever drawing skills he has in reproducing the figures. *The changes in performance over time can be fully accounted for in terms of learned responses without recourse to autonomous changes in a hypothetical trace field.*

We have concluded that information and skills acquired during the preliminary training enable *S* to reconstruct the designs after true forgetting has occurred. Amount of forgetting for the details of the figures was assumed to vary with the

length of the retention interval. Our argument would be strengthened if the amount of forgetting could be manipulated directly and the differential effects of preliminary training demonstrated under these conditions. One method for so manipulating the degree of forgetting is to create conditions for retroactive inhibition. Our theoretical analysis would then lead us to predict that differences in preliminary training would significantly influence susceptibility to retroactive inhibition. Experiment III attempts to show that such is indeed the case.

EXPERIMENT III: THE EFFECTS OF PRELIMINARY TRAINING ON RETROACTIVE INHIBITION

The purpose of Experiment III was to investigate the effects of different conditions of preliminary training on retroactive inhibition. The hypothesis tested was that the more information the preliminary training provided concerning the principles of the code and the organization of the series the smaller would be the amount of retroactive inhibition. A further hypothesis was that if the original learning and the interpolated learning involved different principles of organization, there would be less retroactive inhibition than if the same principles of organization applied to both learning tasks.

Method

Experimental design. The conventional design for experiments on retroactive inhibition was used. For the experimental groups, the test of original learning was followed by an interpolated learning task and test. The control groups rested for a period equal to that occupied by the interpolated task.

Three pairs of experimental and control groups with different conditions of preliminary training were used: Condition I (code training), Condition II (pair training), and Condition IV (figure training). Each of the experimental groups was, in turn, divided in two subgroups.

TABLE 7
SUMMARY OF DESIGN OF EXPERIMENT III

Relation between Original Learning and Interpolated Learning	Cond. I		Cond. II		Cond. IV	
	Training Sequence	*N*	Training Sequence	*N*	Training Sequence	*N*
Same	A—A*	7	A—A	6	A—A	6
	S—S	6	S—S	6	S—S	6
		13		12		12
Different	A—S	7	A—S	6	A—S	6
	S—A	6	S—A	7	S—A	5
		13		13		11
Control	A	5	A	5	A	5
	S	6	S	6	S	7
		11		11		12

* A refers to training in the principle of addition, S to training in the principle of subtraction.

For one of the subgroups, original and interpolated learning were governed by the same principles, for the other subgroup by different principles. The experimental design is summarized in Table 7. This design made it necessary to introduce some modifications into the conditions of preliminary training and principles of the code as compared with Experiments I and II. These modifications will be described in the following sections.

Preliminary training. The general procedure and instructions for the different conditions of preliminary training differed from those used in the earlier experiments in two respects. First, only one of the four breakdown pairs of each code was used in the training prior to original learning. Each of these breakdowns was presented twice, so that the training stimuli for Conditions I and II consisted of 16 paired designs and for Condition IV of 32 single designs. Second, the experimental groups were given further training prior to the interpolated learning. During that training, each code was again represented by one breakdown pair, different from that used in the original training. Each of the breakdown pairs again appeared twice.

Differentiation of code principles. One of the variables in the experiment was the relation between the principles of organization governing original and interpolated learning. Would there be more retroactive inhibition if the rule were the same for both tasks than if it were different? For purposes of making this comparison, the rules of the code used previously were differentiated into two separate sets of rules as follows.

Breakdown pairs, it will be recalled, are formed by removing a line from one member of a pair and adding it to the other member. As Fig. 1 shows, there are for each code two breakdown pairs in which a line is removed from the first member and added to the second (breakdown pairs *a* and *b*), and two breakdown pairs (*c* and *d*) in which the line is removed from the second member and added to the first. With reference to the first member, these two classes of breakdowns follow the principles of subtraction and addition respectively. These principles of addition and subtraction provided us with two separate sets of rules which could be used in original and interpolated learning.

Under each condition of preliminary training, half the experimental *Ss* received training in the same principle before original and interpolated learning, but with different specific breakdown pairs; the other half of the *Ss* were trained in different principles before the two learning tasks. Of those who were trained in the same principle, half were trained in the principle of addition, and half in the principle of subtraction. For half of those who were trained in different principles, the principle of addition was used in the original learning and the principle of subtraction in the interpolated learning; for the other half the order was reversed.

Memory series. Both the original and the interpolated memory series consisted of 16 figures. These 16 figures formed eight breakdown pairs, one from each of the eight codes. The cards were exposed at a 3-sec. rate, with 10 sec. between series. Both series were presented four times. This number of presentations was chosen after preliminary experimentation had shown that it would cause the different experimental groups to be approximately equal in the number of individual designs retained. Since the experiment was concerned with differences in amount of retroactive inhibi-

TABLE 8

AVERAGE NUMBER OF DESIGNS CORRECTLY REPRODUCED ON TEST AND RETEST OF ORIGINAL LEARNING AND TEST OF INTERPOLATED LEARNING

Relation between OL* and IL*	Cond. I			Cond. II			Cond. IV		
	Test of OL	Test of IL	Retest of OL	Test of OL	Test of IL	Retest of OL	Test of OL	Test of IL	Retest of OL
Same	14.54	15.08	13.46	14.17	15.42	11.25	13.08	13.50	8.42
Different	13.23	15.00	12.38	12.92	14.07	10.92	13.09	13.00	10.36
Control	13.63		13.82	14.18		14.27	13.33		13.58

* OL refers to original learning, IL to interpolated learning.

tion, it was desirable to have the different groups as nearly equal as possible in degree of original learning. With a shorter and more homogeneous series than had been used in Experiment I, four presentations of the series were sufficient to equalize the various groups in the number of individual designs retained. As will be seen, however, differences in degree of code conformity inevitably remained.

A retention test was given immediately after the end of the original learning. For the experimental *Ss*, the interpolated training and test came immediately after the retention test. Retention for the original learning was retested immediately after the test of interpolated learning. The control *Ss* read passages from magazine articles for a period of time equal to that occupied by the interpolated activity for the experimental groups. Following this reading period, the control *Ss*' memory for the original learning was retested.

Subjects. The *Ss* were undergraduate students at the University of California. They did not know the purpose of the experiment. They were assigned to the experimental groups at random.

RESULTS

The criteria for evaluating the effects of the preliminary training were the same as in the previous experiments. Only *Ss* who gave at least 80 per cent correct reproductions during the preliminary training were used in the experiment.

Preliminary examination of the data showed that training in the principles of addition and subtraction gave equivalent results. Results for the two types of training are, therefore, pooled under all conditions. Retention scores are presented separately for groups trained on the same principle during original and interpolated learning and for groups trained on different principles.

Original learning. Table 8 shows the average number of individual designs reproduced correctly on the first test of original learning by the experimental

TABLE 9

AVERAGE INDEX OF CODE CONFORMITY ON TEST AND RETEST OF ORIGINAL LEARNING AND TEST OF INTERPOLATED LEARNING

Relation between OL and IL	Cond. I			Cond. II			Cond. IV		
	Test of OL	Test of IL	Retest of OL	Test of OL	Test of IL	Retest of OL	Test of OL	Test of IL	Retest of OL
Same	6.38	6.85	6.08	5.75	7.17	3.08	4.00	4.75	1.25
Different	5.00	6.77	5.38	4.46	5.08	2.77	1.82	2.45	.54
Control	4.45		5.45	4.09		4.00	3.33		3.25

TABLE 10

PERCENTAGES OF RETROACTIVE INHIBITION AS MEASURED BY NUMBER OF DESIGNS CORRECTLY REPRODUCED AND INDEX OF CODE CONFORMITY

Relation between OL and IL	Cond. I		Cond. II		Cond. IV	
	Reproductions	Index	Reproductions	Index	Reproductions	Index
Same	8.96	22.34	21.65	45.23	36.82	67.98
Different	7.49	11.99	15.39	36.49	22.34	69.04
Combined	8.22	17.16	18.38	40.68	29.89	68.49

and control groups following different conditions of preliminary training. The differences among experimental groups are small and not significant ($F = 1.00$). As has already been found in Experiment I, differences among training groups in the retention of individual designs tend to disappear with a sufficient amount of practice. With a short series drawn from a restricted group of stimuli, four presentations of the series are sufficient to equalize the retention of individual designs. (In Experiment I, with a longer series drawn from a larger group of stimuli, similar results were obtained after eight presentations of the series.)

As Table 9 shows, there were considerable differences among the groups in the degree of conformity to the principles of the code. As in Experiment I, Condition I yields the highest degree of code conformity, with Conditions II and IV following in that order. Analysis of variance shows the differences among experimental groups to be significant ($F = 10.26$, $df = 2$ and 71, $p < .01$). We note that there is considerable variability among the subgroups within a given condition of training although the rank order of the conditions is generally maintained. Such variability is often unavoidable when a fixed number of learning trials rather than a criterion of performance is used. All differences in original learning will, of course, be taken into account in the computation of retroactive inhibition.

For both measures of retention, the combined experimental groups under each condition of training are not significantly different from their corresponding control groups.[6]

Interpolated learning. Table 8 shows the average number of individual designs correctly reproduced by the various groups on the test of interpolated learning, and Table 9, the average indices of code conformity. The rank order of the conditions is the same as on the original test. Performance on the test of the interpolated activity tends to be higher than on the test of original learning. The improvement appears to be greater for Conditions I and II than for Condition IV. However, in the absence of control groups which learn the interpolated task without prior practice it is impossible to evaluate the amount of positive transfer from original to interpolated activity.

Retroactive inhibition. We now turn

[6] This statement is generally true when combined experimental groups are compared, under each condition of training, with their corresponding control groups. When each individual subgroup is compared with the control group none of the differences in the number of reproductions is significant. In the case of the index of code conformity, for which there was considerable variability among subgroups, there are two cases—I-Same and IV-Different—in which the difference between an experimental subgroup and the control group barely reaches the .05 level. All differences in original learning will, of course, be taken into account in the computation of measures of retroactive inhibition.

to the main results of the experiment, viz., the effects of different conditions of preliminary training on retroactive inhibition. Table 8 shows the average numbers of correct reproductions of individual designs obtained on the retest of original learning. Table 9 presents the same information for the index of code conformity. For each of the experimental groups, the percentage of retroactive inhibition is shown in Table 10. Since experimental and control groups were not strictly equated in original learning, the following procedure, recommended by McGeoch (7), was used in the computation of the percentages of retroactive inhibition. All retention scores were first converted into percentages of the amount retained on the first test of the original learning. It is to these percentages that the conventional formula, control minus experimental/control, was then applied. The percentages of retroactive inhibition, both for reproduction of individual designs and for the index of code conformity, are presented graphically in Fig. 11 and 12. The upper parts of these figures present the interference effects separately for groups trained on the same principle and for groups trained on different principles during original and interpolated learning. The bottom parts of the figures show the percentages of retroactive inhibition for the combined groups under each of the conditions of training. These combined values provide an over-all summary of the relation between preliminary training and retroactive inhibition.

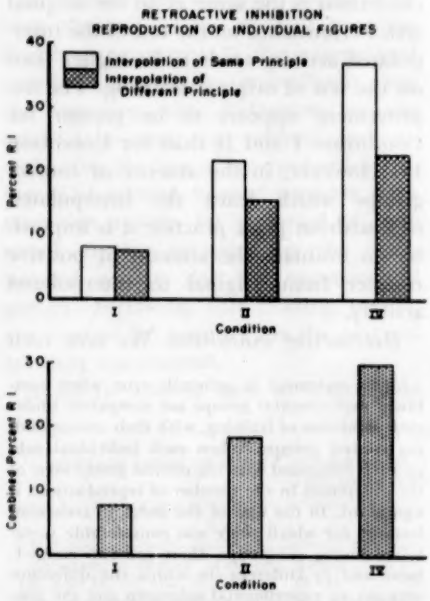

FIG. 11. Percentages of retroactive inhibition as measured by number of correct reproductions in Experiment III.

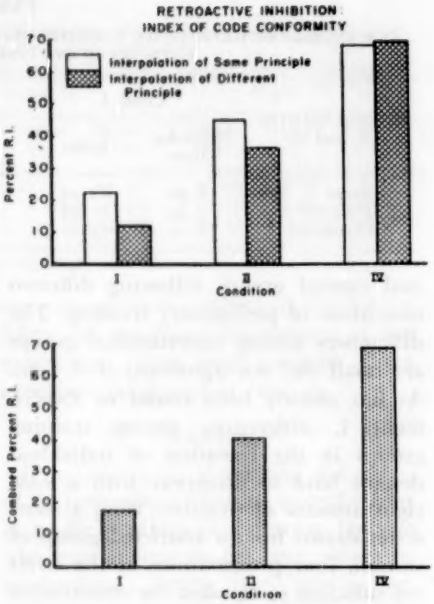

FIG. 12. Percentages of retroactive inhibition as measured by the code conformity index in Experiment III.

Clearly, amount of retroactive inhibition varies with the condition of pre-

TABLE 11

TESTS OF SIGNIFICANCE OF DIFFERENCES BETWEEN EXPERIMENTAL AND CONTROL GROUPS IN AMOUNT OF RETENTION LOSS FOR NUMBER OF CORRECT REPRODUCTIONS AND INDEX OF CODE CONFORMITY
(Entries are values of *t*)

Relation between OL and IL	Cond. I		Cond. II		Cond. IV	
	Reproductions	Index	Reproductions	Index	Reproductions	Index
Same	1.54	1.77	5.02**	2.96**	5.02**	5.80**
Different	1.14	.70	2.09*	2.35*	2.09*	2.38*
Combined	1.22	1.30	2.98**	2.65*	3.08**	5.32**

* Significant at the .05 level of confidence.
** Significant at the .01 level of confidence.

liminary training. For both measures of retention, Condition I shows the least amount of interference, Condition IV the greatest, and Condition II an intermediate amount. In general, training on the same principle in original and interpolated learning produces more retroactive inhibition than does training on different principles.

For purposes of statistical analysis, the difference between original test score and retest score was determined for each *S*, both for the number of individual designs correctly reproduced and for the index of code conformity. To establish the presence of retroactive inhibition, the significance of the differences in mean retention loss between experimental and control groups was tested under each condition of training. The results are presented in Table 11. For both measures of retention, there are significant differences between experimental and control groups for Conditions II and IV, but not for Condition I. There is, then, significant retroactive inhibition for Conditions II and IV, but not for Condition I.

The next step was to test the significance of differences in retention loss (retroactive inhibition) among the experimental conditions. Analyses of variance were performed on the retention-loss scores of the experimental groups. For both retention measures, condition of preliminary training is a significant determinant of the amount of retention loss. For reproduction of individual designs, F is 6.77, which for 2 and 68 df is significant at better than the .01 level of confidence. For the code conformity index, the F ratio is 19.45, which is also significant beyond the .01 level. The two measures of retention give different results when groups trained on the same principle and groups trained on different principles are compared. Similarity of original and interpolated training does not significantly influence retention loss for individual designs although the differences consistently favor the groups trained on different principles ($F = 2.64$, $df = 1$ and 68, $p > .05$). In the case of the code conformity index, however, the groups trained on the same principle do show significantly less retention loss than do those trained on different principles ($F = 4.79$, $p = .01$–$.05$). In neither case is there a significant interaction between conditions of preliminary training and similarity of principles.

The statistical analysis confirms our conclusion that conditions of preliminary training significantly determine susceptibility to retroactive inhibition. The more explicitly the preliminary training provides *S*s with rules for the organization and reconstruction of the

material, the less interference there is between two series of items obeying these principles. Of the two measures of retention used, the index of code conformity is more sensitive to the influence of preliminary training; it is the decrement in this index only which is significantly influenced by the similarity of the two learning tasks. This last finding is, of course, not surprising, for the index was specifically designed to measure the degree to which *Ss*' reproductions are governed by learned rules of organization.

Conclusions

In analyzing the conditions of retroactive inhibition McGeoch wrote as follows: ". . . retroactive inhibition decreases with an isolation of the interpolated activity from the original, an isolation which may be brought about in a number of different ways, among which instruction and set are very influential" (6, p. 479). The results of this experiment provide additional evidence for McGeoch's conclusion.

Original and interpolated learning can be isolated from each other to the extent that the learner responds to the two tasks in specific ways which help to maintain their separate identities. When *S*'s task is the reproduction of a series of similar items, such as nonsense syllables or geometric designs, any associative cues which serve to differentiate one item from the other, both within lists and between lists, will serve to increase isolation and to decrease retroactive inhibition. Classification of items in terms of a set of general rules or principles will further such differentiation of the individual items and serve to protect them from interference.

Let us now apply this general argument to the specific materials of this experiment. The more explicit the preliminary training in the principles of the code the more are *Ss* ready to identify (*a*) each pair as belonging to a specific code set and (*b*) each single figure as a member of a pair linked to a second member by specific rules. Such differential reactions to each pair are probably emphasized and made more effective by explicit verbalization of the rules of classification. Hence there is maximum resistance to interference following explicit training in the principles of the code (Condition I). The *Ss* trained under Condition II rank second in susceptibility to retroactive interference. These *Ss* may be assumed to have acquired a disposition to classify items in accordance with the rules of the code, or at least as pairs, but in the absence of explicit instructions this disposition is probably less strong and less general than it is for *Ss* trained under Condition I. In addition, the differential responses to the items of the memory series would receive less emphasis from explicit verbalization. Finally, *Ss* trained under Condition IV show the highest amount of retroactive inhibition. The preliminary training of these *Ss* could not produce strong dispositions for the differential classification of the items of the memory series in accordance with the rules of the code, nor were their differential responses emphasized by explicit verbalization. The preliminary training did, of course, result in general familiarity with the items of the memory series but did not provide for the differential classification of the items which we consider crucial for resistance to retroactive interference.

The effects of preliminary training are probably not limited to determining the differential responses to the stimuli at the time of original and interpolated learning. At the time of the retention

test, the information acquired during the preliminary training may provide different degrees of support for the reconstruction of the items of the memory series. Let us assume, as we have throughout, that true forgetting in Woodworth's sense (10) occurs during the retention interval so that the details of the stimulus figures are incompletely remembered at the time of the retention test. To the extent that *Ss* have information concerning the rules governing the composition of the series, they are able to supplement these incomplete details by reconstructing other stimulus figure features on the basis of this information. The more explicit the information is the more successful will such reconstructions be. We conceive, then, that differences in preliminary training may influence amount of retroactive inhibition in two ways: (*a*) by determining differential responses to the items in the series and (*b*) by providing *Ss* with varying amounts of information for reconstructing the memory material on the basis of incompletely remembered specific stimulus items.

SUMMARY AND GENERAL CONCLUSION

This series of experiments has demonstrated that learned rules of organization can systematically influence both the amount and quality of retention. Memory materials governed by a consistent set of principles were used. By manipulating the conditions of preliminary training it was possible to influence not only the number of individual items retained but also the quality of the errors in *Ss'* reproductions. The more explicit *Ss'* preliminary training in the principles governing the stimulus materials the more their reproductions conformed to these principles. The effectiveness of such preliminary training increases with the retention interval. As the interval is lengthened conformity to the principles increases progressively; there is a growing tendency to omit or to rectify errors which violate the general principles. Finally, the more explicit the training the less susceptible the memory material is to retroactive inhibition.

It is possible, then, to manipulate amount and quality of memory change by familiarizing *S* with the stimulus material and by providing him with general rules for classifying and ordering the individual items. As the detailed features of the stimuli are forgotten, *S* makes increasing use of these rules in reconstructing what he has learned.

The fact that memory shows systematic and often progressive changes over time has been invoked as evidence for the development of memory traces in accordance with principles of perceptual organization. Our results show that such progressive systematic changes can be produced under controlled conditions of associative learning. To account for results such as ours, no appeal to dynamic changes in the trace system is necessary. Our findings are entirely consistent with Woodworth's (10) view that (*a*) there is true forgetting for the memory material and (*b*) *S* brings to bear upon his reproductions whatever habits he has in connection with the class of materials to which the memory items belong.

Our demonstration that systematic memory change can be produced under controlled conditions of associative learning is not, of course, positive evidence against the hypothesis of progressive development of the memory trace. Direct evidence against the hypothesis has, of course, been presented, notably

by Hanawalt (3) and by Hebb and Foord (4). The results of these experiments further support a reinterpretation of systematic memory changes in the framework of associative learning. We have explored some of the specific conditions under which systematic changes can be produced. The more fully we can specify the antecedent conditions of memory change the less tenable becomes the appeal to hypothetical trace systems which so far have defied positive experimental verification.

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